

TABLE 5.—Flood stages in Pacific drainage during February, 1918.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
<i>Merced:</i>	<i>Feet.</i>			<i>Feet.</i>	
Merced Falls, Cal.....	7			6.5	24
<i>Willamette:</i>					
Eugene, Oreg.....	10	7	7	11.5	7
Oregon City, Oreg.....	10	7	10	12.2	8-9
Portland, Oreg.....	15			13.8	8-9
<i>Santiam:</i>					
Jefferson, Oreg.....	10	7	7	10.5	7

## ICE IN RIVERS, 1917-1918.

By ALFRED J. HENRY and others.

[Dated: River and Flood Division, Weather Bureau, Mar. 25, 1918.]

The severe and long-continued cold of the winter of 1917-18 caused heavy ice to form on northern rivers, as was to be expected, and pushed the southern limit of heavy ice a little farther south than usual.

Ice began to form on the Ohio as early as December and navigation on the upper and middle stretches of that stream was practically suspended by the middle of the month. The weather during January, 1918, continued unseasonably cold and there was practically no ice movement in any of the streams.

In December the ice in the Ohio had gorged at many places, the most extensive on the upper river being in the tortuous bends immediately above Sugar Creek, an insignificant stream that empties into the Ohio between Warsaw, Ky., and Rising Sun, Ind. (see fig. 1). A second extensive gorge formed in the vicinity of Evansville, Ind.

The termination of the cold weather came in the closing days of January when a day or so of thawing weather with rain was the occasion of a break-up of the ice in the southern tributaries of the Ohio, the ice passing into the trunk stream on fairly high stages. Short periods of cold weather with night temperatures considerably below freezing were the rule until about February 5, when a decided rise in temperature set in over the Ohio Valley and mild temperatures for the season continued for nearly 10 days.

The most serious gorge in the Ohio, as above stated, was the one that formed above Sugar Creek between Cincinnati and Louisville. Fortunately this gorge did not wholly prevent the flow of water beneath it and as a consequence the channel below the gorge was open and the river was at a comparatively low stage when the gorge finally broke on February 12, after holding firm for 58 days. The history of this gorge is fully set forth in the report of Meteorologist W. C. Devereaux, in charge of the Cincinnati district, page 86.

Recognizing the importance of preserving an account of the ice blockade along the Ohio and Mississippi, the following details are presented by the Weather Bureau officials in charge of respective districts, Pittsburgh, Pa., to Cairo, Ill., on the Ohio and St. Paul, Minn., to Vicksburg, Miss., on the Mississippi.

## MISSISSIPPI DRAINAGE.

## OHIO RIVER.

## Pittsburgh, Pa., river district.

Low temperatures set in on December 1 and continued almost uninterruptedly to February 5, a period of 67 days, with only 6 days when the temperature was above the normal. The accumulated deficiency for December was 317°; for January, 268°; and for the 5 days in Feb-

ruary, 88°; or a total deficiency of 673°. The accumulation of snow on the ground ranged from 5 to 10 inches over the Monongahela watershed and from 10 to 30 inches over the Allegheny watershed. Ice formed in the rivers from 1 foot to nearly 3 feet in thickness.

Moderately heavy rains in West Virginia, together with higher temperatures on January 27 to 29, melted most of the snow in the Monongahela Valley, causing a break-up in the Monongahela River. The ice formed an immense gorge below Morgantown and another near Brownsville, the water backing up over the Baltimore & Ohio Railroad tracks at Morgantown, with a stage of 39 feet at Lock No. 10, and 25 feet at Fairmont at 2 p. m. of January 29. The gorge at Brownsville backed up the water over the low ground of that place and shut down many mines in that vicinity, reaching a stage of 21.6 at Greensboro, Pa., on February 10. As the ice in gorge formation moved along it carried away and sunk quite a number of barges and three steamboats. Ice also gorged in the Ohio River near Steubenville, Ohio, and below Wheeling, W. Va., backing up the water at Wheeling to 37.8 feet on February 11. A portion of the ice from the Kiskiminetas lodged in the Allegheny River below Freeport, Pa., but the Allegheny remained frozen throughout.

After the thaw in the latter part of January another period of cold weather set in, with more snow, and the Monongahela again froze over with new ice. Higher temperatures and moderate rains on February 19 caused a break-up in the ice in the Monongahela. The gorges at Morgantown and Brownsville broke up, the ice floated a short distance and disappeared, probably sinking from the weight of sand and mud. None of this ice reached Pittsburgh. The Allegheny ice broke up, beginning in the lower river, and coming out in patches to above Warren, Pa. A gorge formed below Corydon, Pa., a short distance above Warren, backing the water over the town of Corydon, and causing much damage. The gorges in the Ohio also moved out on February 19.

Reports at 8 a. m. of Wednesday, February 20, showed that heavy rain had occurred throughout the watersheds of the Allegheny and Monongahela Rivers, with high temperatures melting the snow and ice in the mountains, causing rapid rises in all streams. At 10 a. m. a flood warning was issued for a stage of 28 feet at Pittsburgh by the next morning. After further reports were received the stage for Pittsburgh was reduced to 27 feet, and a warning issued for 37.5 feet at Wheeling Thursday night. The crest of the flood passed Pittsburgh at 6 a. m. on Thursday, the 21st, with a stage of 27.1 feet, and Wheeling at midnight, Thursday, with a stage of 37.9 feet.

Never before have the conditions as to the accumulated depth of snow on the ground and the heavy formation of ice in the rivers assumed such threatening and dangerous character. The water equivalent of the snow on the ground ranged from about 1 inch over the Monongahela Valley; about 2 inches over the Youghiogheny; and from 2 to 3.50 inches over the Allegheny Valley. Owing to the small amount of rain during January and during the first part of February, and with rising temperatures after February 5, the snow gradually became less and the ice more or less rotten and honeycombed. The ice all moved out of the Youghiogheny without loss, as did also the ice in the Allegheny, with the exception of the gorge formation near Corydon. The destruction of the property along the Monongahela was caused by immense ice gorges with moderate stages of water. The flood of February 20-21 was caused by heavy rain and melting snow; it passed without material loss, and completely cleared all streams of ice.

The direct loss to property due to ice gorges as estimated was one coal tipple destroyed; five tipples damaged; three steamers sunk—but salvaged—and about 20 coal flats sunk. A great loss was entailed by suspension of mining and shipping of coal. Many mines were closed by high water and owing to railroad congestion the shipment of coal was curtailed very little, being shipped by water for several weeks.

## SUMMARY OF ESTIMATED LOSSES.

Money loss due to destruction of property.....	\$100,000
Money loss due to suspension of business.....	200,000
Money saved by warnings.....	500,000

—Henry Pennywell, Meteorologist in Charge.

## Parkersburg, W. Va., river district.

A gorge formed on January 31, 1918, 8 miles below Dam 14, Ohio River, extending 20 miles down the river. This gorge went out at 5.30 a. m., February 11, breaking at a stage of 35 feet. The thickness of the gorge was about 12 feet. Resulting damage, about \$1,500.

At Dam 15, Ohio River, the gorge moved at 5 a. m., February 11, and gorged again 3 miles below the dam, when the river at the dam rose from 15 feet to 26.6 feet. The gorge broke again at 2:20 p. m. the same day, and the river was clear at 4 p. m. The thickness of the gorge was about 12 feet. Resulting damage was about \$1,500.

Packed ice formed in the Ohio from Dam 19, Ohio River, to Parkersburg, a distance of about 7 miles, on January 12, 1918, and held until 6:10 p. m., February 9, when a movement of 600 feet took place, with a stage of 17 feet at Dam 19. No damage resulted. The ice moved again at 6 a. m., February 10, with a stage of 23 feet at Dam 19, and

wrecked both steel light towers on the lock wall of Dam 19. There was no ice gorge with the movement. Resulting damage, about \$600.

On December 22, 1917, a gorge formed at the foot of Buffington Island, about 5 miles above Dam 22, Ohio River, and moved out on February 10, 1918. This was a small gorge, probably about 5 feet in thickness. No damage resulted.

Early in January, 1918, an ice gorge formed about 5 miles above Middleport, Ohio. This gorge went out on February 10, without doing damage. This was also a small gorge, probably about 5 feet in thickness.

Early in January another small gorge formed 7 miles below Middleport, Ohio. This gorge also went out on February 10, without doing damage.

On January 29 a gorge formed at Nicolette on the Little Kanawha River, extending up the river about 15 miles, with a thickness of 10 feet. This gorge did not go out, but melted and sank, causing no damage.

On January 29 the ice went out of the Little Kanawha River below Dam 1. This ice movement caused an approximate loss of \$1,500 to river craft at Parkersburg.

Approximate total loss from ice gorges, \$6,600; from other ice movements in the district, \$3,000.—*Henry C. Howe, Meteorologist in Charge*

### *Cincinnati, Ohio, river district.*

*Air temperatures and ice conditions.*—The temperature over the Cincinnati district during the late fall of 1917 was unseasonably low, and specially so during the last 10 days of November when it was considerably below freezing nearly every day. The river stages were low and the water was cold when the severe cold wave of December 8 swept over the Ohio Valley. The temperature at Cincinnati fell to 2° below zero on that day, and the weather continued very cold with temperature near zero during the following nine days.

Light ice formed in the Ohio River and its tributaries during the night of December 8-9, and the tributaries froze over at many places during December 9 and 10. In the Ohio ice continued to form so rapidly that practically all navigation had been suspended by the morning of the 10th. During that night the river gorged at Fernbank Dam, about 13 miles below the Cincinnati gage, due partly to the obstruction offered by the wickets which had not been lowered. This gorge extended to the Cincinnati gage and a few miles above on the morning of December 12. The wickets at the dam were lowered on the 11th but the ice did not move between Cincinnati and Fernbank until the afternoon of the 12th. On December 13, 14, and 15, the ice in the Ohio became heavier but continued to move, except occasionally at the sharp bends in the river where temporary gorges formed. At 3 a. m. December 16 a permanent gorge was formed at Dam No. 39, a short distance above the mouth of the Kentucky River. Although there were movements in the ice at different times in other portions of the rivers in the Cincinnati district, the gorge formed in the sharp bends of the river above Dam No. 39, and later known as Sugar Creek gorge, held firm from December 16, 1917, to February 12, 1918.

Except for a few mild days from December 19 to 24, the weather continued very cold, and the two-months period of severe cold, from December 8, 1917, to February 7, 1918, was the longest on record for the Ohio Valley. At Cincinnati the temperature was below zero on 16 days and only slightly above zero on several other days. The lowest during December was 13° below zero and during January 16° below zero, both of which are the lowest of record for the respective months. Along the lower stretches of the river the weather was even colder than at Cincinnati. At Vevay, Ind., five miles below Dam No. 39, the temperature was below zero on 22 days, the lowest for December being 20° below zero and for January 24° below zero.

The ice gorges in the Ohio River in this district formed in the lower part of the river and gradually extended up the river with the advance of the season. The first permanent stops of the ice at the various points, beginning at the lower end of the district, were as follows:

Ice stopped at Dam No. 39 at 3 a. m., December 16, 1917.  
Ice stopped at North Bend during the night of December 16-17.  
Ice stopped at Cincinnati at 3 p. m., December 17, 1917.  
Ice stopped at Maysville at 3:10 p. m., January 1, 1918.  
Ice stopped at Portsmouth at 4:30 p. m., January 3, 1918.  
Ice stopped at Dam No. 29 at 12:10 p. m., January 12, 1918.  
Ice stopped at Dam No. 28 at 8 p. m., January 12, 1918.  
Ice stopped at Dam No. 26 about noon, January 13, 1918.  
Ice stopped at Gallipolis at 4:30 p. m., January 13, 1918.  
Ice stopped at mouth of Kanawha during the night of January 19-20, 1918.

On December 17, 1917, gorges in the Ohio above the mouth of the Kanawha cut off the supply of moving ice from above and the few days of mild weather beginning on December 18 prevented the formation of new ice. New ice began forming again on December 26, and considerable ice came out of the upper Ohio during the last five days of December. The gorges then gradually extended up to near the mouth of the Big Sandy. Rain, with temperature slightly above freezing,

over the southern tributaries on the afternoon of January 5 and during the 6th caused a slight rise in the river and again delayed the growth of the gorges, but heavy ice continued in the Ohio between the mouth of the Kanawha and the mouth of the Big Sandy. With the occurrence of the coldest weather on record for January, on the 12th, gorges formed rapidly at Dams Nos. 29, 28, and 26, and at Gallipolis. Due to both rivers freezing over above Point Pleasant and cutting off the supply of moving ice, and the cross-currents, the river did not freeze over at the mouth of the Kanawha until the night of January 19-20. This was the first time that the Ohio River had been frozen over at the mouth of the Kanawha in 23 years.

Practically all rivers in the district were frozen over from January 20 to 27, 1918. The ice was very hard, due to the continued cold weather. The height of the water gradually rose from about 12 feet to about 22 feet from Cincinnati to the mouth of the Kentucky between the middle of December and January 27. There was traffic on the frozen river, and at several places heavy loads crossed on the ice with horses and on automobiles.

*Floods in southern tributaries.*—On the afternoon of January 26, 1918, moderate rains fell over the headwaters of the southern tributaries and these streams began rising, and the ice broke in the Tug and Levisa Forks of the Big Sandy River. During the night of the 27th-28th another storm caused heavy and general rains over the valleys south of the Ohio River. On the morning of the 28th the Kanawha-New, Guyandotte and Big Sandy Rivers were rising rapidly and the ice had broken. These rivers continued to rise rapidly during the 28th, and the following crest stages, which are the highest on record, were reached: Logan on the Guyandotte, 27 feet at 1 p. m., 28th; Williamson on the Tug Fork of the Big Sandy, 38.3 feet about midnight of the 28th-29th; and Pikeville on the Levisa Fork of the Big Sandy, 50 feet at 9 p. m. on the 28th. The crest stage at Pikeville was 9 feet above the previous high-water record. The crest at Louisa on the Big Sandy was 47 feet, or 1.3 feet below the high-water record. The crests were below the flood stages at all places in the Kanawha Valley. The Licking River rose considerably and the ice broke at Farmers, Ky., on the North Fork, but the ice did not break in the Licking itself or in the South Fork.

*Rise and breaking of gorges in the Ohio.*—The rise in the Ohio River below the mouths of the Kanawha, Guyandotte and Big Sandy Rivers, began during the forenoon of the 28th, and after the river had risen about 12 feet the ice began to break. Because of the more rapid discharge of the Big Sandy the ice began breaking first at the mouth of that river. In the Big Sandy, 3 miles above the mouth, the ice started moving at 8 a. m. of the 28th and by noon most of the ice had passed into the Ohio where it piled several feet high over the banks. At Dam No. 29, 3 miles below the mouth of the Big Sandy River, the ice started moving slowly at 12:55 p. m., the same day.

At the mouth of the Kanawha the ice started moving into the Ohio at 3 p. m. on the 28th, and after a short time an open space appeared in the center of the Ohio in which a distinct whirl in the water was visible. The ice around this whirl gradually broke up, and the ice from the Kanawha gorged both up and down the Ohio and piled high on the opposite bank. At Gallipolis, 4 miles below the mouth of the Kanawha, the ice did not break until 9:40 p. m. that night, and at Dam No. 26, 9 miles farther down, the ice broke about midnight. The following morning at 5:40 it broke at Dam No. 28, 6 miles below the Guyandotte and 7 miles above the Big Sandy.

At 7 a. m. on January 29 the ice was moving from the mouth of the Kanawha nearly as far down as Portsmouth. The river above Portsmouth was about 15 feet higher than below. At Portsmouth the ice moved for one minute at 5:15 a. m., but the general movement did not start until 9:30 a. m. Ten minutes later the ice broke at Dam No. 31, 3 miles down the river, and at Buena Vista, 22 miles below Portsmouth, two hours later. During the afternoon of the 29th the ice jammed between Portsmouth and Maysville, causing an artificial rise of about 10 feet in the river at Portsmouth, where the ice stopped running from 4:15 p. m. to 5:20 p. m. The crest stage at Portsmouth was 49.5 feet.

At Maysville the ice broke at 11:20 p. m. of the 29th, and the breaks apparently moved down the river quite steadily during the night, reaching Coney Island at the upper end of Cincinnati at 7 a. m. on the 30th.

At Cincinnati the river began rising rapidly shortly after 7 a. m. January 30, and at a stage of about 28 feet the ice broke at 10 a. m. The river rose 7.5 feet in the next hour and the ice was moving at the rate of about 6 miles per hour. The ice began moving at Fernbank Dam, 14 miles below the Cincinnati gage, at 11:15 a. m., and after moving slowly for 30 minutes it stopped and gorged during the afternoon as far up as Coney Island. That night the gorge broke at Cincinnati at 11 p. m., and the ice started moving rapidly past Fernbank at 11:45 p. m. This break carried the ice through the heavy gorge at North Bend and past Lawrenceburg and Aurora. Boats and barges which were carried out of the Cincinnati Harbor were held in the ice just below Rising Sun, Ind.

As soon as the first big rise in the river had passed the ice began to jam in the sharp bend in the river at North Bend, Ohio, and a

new gorge was formed which extended up to Cincinnati. The ice at Fernbank Dam within this gorge stopped moving at 10:03 a. m. January 31. Logs and other debris from the Big Sandy Valley were held in the ice at Fernbank Dam, and boats from the Kanawha Valley were held in the ice a few miles farther up the river.

**Sugar Creek gorge.**—The big gorge between Rising Sun and Dam No. 39 was the only one that held firm during the entire rise. This became known as Sugar Creek gorge, although it was later discovered that the foot of the gorge was 1 mile above Sugar Creek. The gorge proper was located in the sharp bends in the river extending from North Landing, 3 miles below Rising Sun, to the first bend in the river below Patriot, Ind., a distance of 12 miles. This portion of the river

opposite side of the river, with deep valleys cutting through the steep banks at many points.

The first point where the ice began to hold was in the bend at North Landing. Here the top of the bank on the outside of the bend is within 200 feet of the low-water line. Two small valleys break through the bank within a distance of 2 miles, and a portion of the ice moved up these valleys. At two places highway bridges were pushed upstream by the ice, and a fair-sized steel bridge was crushed with the pressure of the ice over the banks. The topography of the banks at other places within the gorge, especially between Gunpowder Bar and Big Bone Island, and between Patriot and Sugar Creek, is favorable for holding the ice.

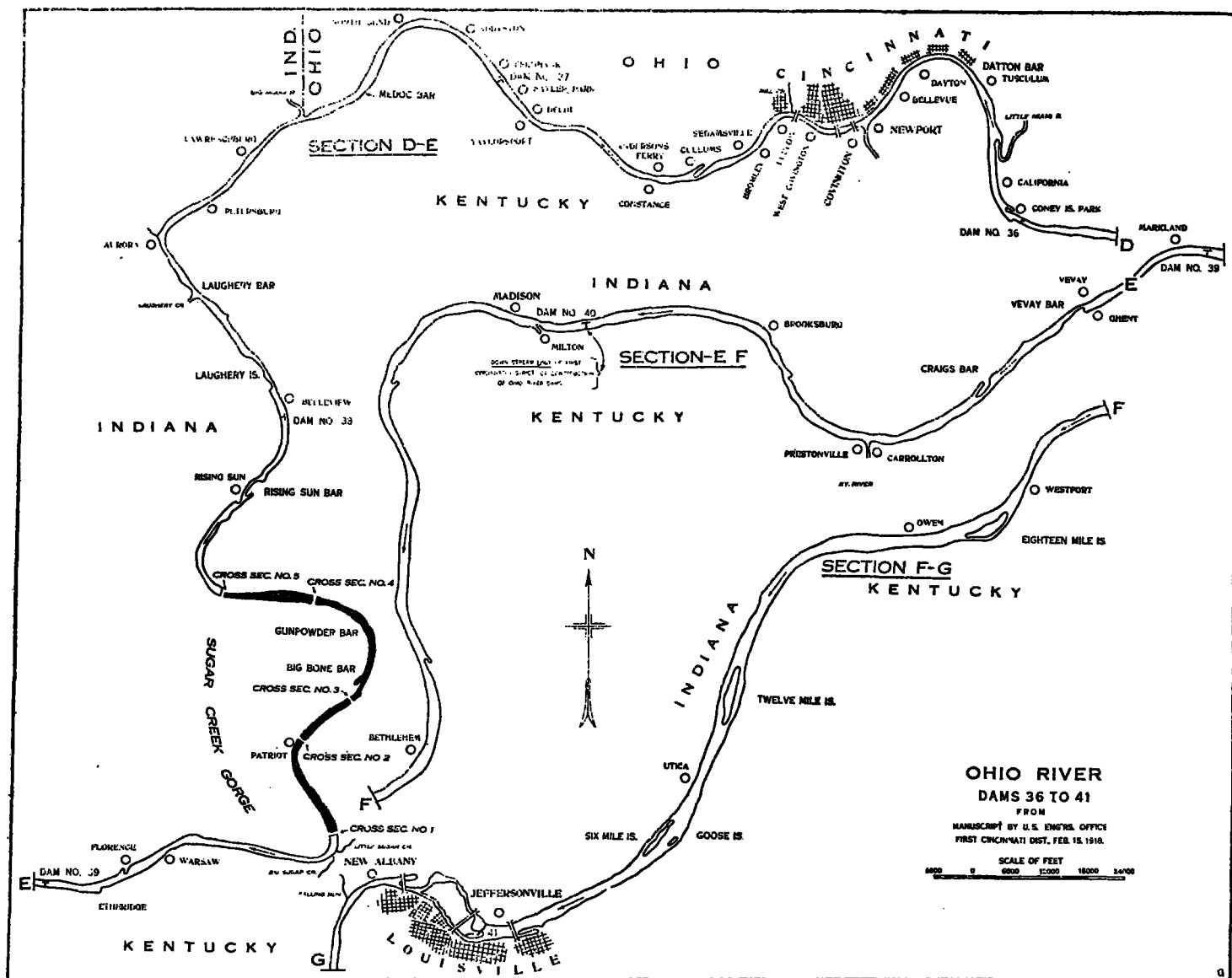


Fig. 1.—Ohio River, Cincinnati, Ohio, to Louisville, Ky.

Portion affected by Sugar Creek gorge is drawn in solid, and shown in detail on Fig. 1a. Cross sections 1 to 5 of Fig. 2 are indicated here by white bars.

is very crooked with irregular banks which project in and form sharp angles. (See fig. 1.) There is one large bar known as Gunpowder Bar, and a short distance below is Big Bone Island, but it is believed the steep and irregular banks and sharp bends were greater factors in holding the gorge than the irregularities in the bed of the river.

Very few portions of the Ohio River show so many sharp bends within a distance of 12 or 15 miles as that portion above Sugar Creek known as the "Ox-bow." From above Rising Sun to below Sugar Creek the river has somewhat the shape of two letters S attached end to end. As shown by the cross sections of the river (fig. 2) the center of the channel is first on one side and then on the other, and at one point the bank is steep and high on one side only, while a few hundred feet farther down the river the nearly perpendicular bank is on the

Much of the ice which had covered the river for a distance of 40 miles above North Landing (see fig. 4) was jammed into the first 10 miles of the gorge, forming great hills of ice, some of which were 30 feet or more high, and pushing far up the valleys and ravines and over the lower portions of the banks. For 2 miles upstream from the foot of the gorge the ice remained smooth, except for a split of crushed ice about 20 feet wide and probably extending to the bottom of the ice. This split started in the center of the channel and extended down to the end of the gorge, being somewhat nearest to the left bank looking upstream. At Patriot, about 3 miles above the foot of the gorge, the ice broke in the middle of the river and pushed out against the banks, turning up great cakes of ice, one of which was nearly vertical and rose 20 feet above the surface. At this point there were also large fields of unbroken

ice. From Patriot up to North Landing both the ice cakes and fields of unbroken ice gradually decreased in size until the fields disappeared, and there remained only a conglomerate mass of crushed ice at the head of the gorge.

This gorge continued to back up the water until the river reached a crest stage of about 58 feet at Rising Sun, Ind., on the morning of February 3. The level of the water then was about 25 feet higher above the gorge than below it. At that time there was a nearly level pool of water extending 104 miles up the river as far as Dam No. 33 above Maysville. Gorged ice covered the river from North Landing to Aurora, and also from North Bend to Cincinnati, but these gorges had but little effect on the flow of the water. The crest at Cincinnati was 61.2 feet at 2 a. m. February 2, 1918. Between 15 and 20 feet of this rise was due to the backwater effects from the Sugar Creek gorge.

As soon as the river above the pool, which extended up to Dam No. 33, had fallen to about the same level it was before the rise began, the river stopped rising above the gorge, showing that the water was passing under the gorge as fast as it was coming down from above.

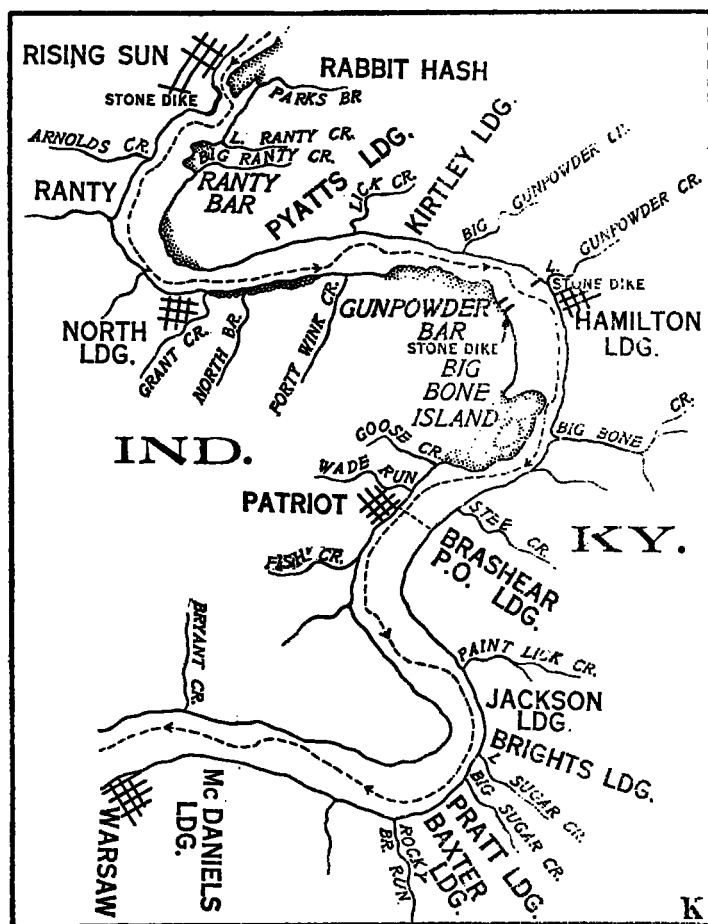


Fig. 1a.—Sugar Creek bend enlarged. (Compare fig. 1 and fig. 2.)

The gorges continued stationary and the river continued to fall slowly for one week.

**Flood and gorge in Licking River.**—Rain and warm weather caused a rise in the Licking River on February 9, 1918. Ice broke at 5 a. m. in the South Fork at Cynthiana, Ky., and the river rose rapidly to near flood stage, and the ice broke in the North Fork at Farmers, Ky., at 1:30 p. m. Both of these tributaries brought considerable water and a large amount of ice into the Licking and a big gorge was formed in that river just below Butler, Ky., about 17 miles below Falmouth. The water backed up as far as Falmouth where the crest stage was just above the flood stage of 28 feet. On the morning of February 10 the water at Butler was much higher than ever known before and the stage was estimated to be 55 feet. This made a very threatening condition for Cincinnati, as a break in the Licking gorge would cause a sudden rise of probably 10 feet or more, and the Ohio River was nearly full at the time. During February 10 and 11 the flood water in the Licking came out slowly under the ice and most of the ice was left in the river. The gorge below Butler moved about 500 feet during the early morning of the 11th, and moved again at 8:40 a. m., but the ice jammed in the bends below and did not reach the mouth of the river at that time.

The gradual decrease of the slope in the Licking, the backwater from the Ohio, and the sharp bends and irregular banks below Butler, prevented the ice from coming out of the Licking. The average slope of low water from Falmouth to Butler, 17 miles, is 2 feet per mile, and for the 35 miles from Butler to the mouth it is  $\frac{1}{4}$  foot per mile. On the morning of February 10, when the crest stage occurred at Butler, the elevation of the water in the Ohio at the mouth of the Licking was practically the same as the elevation of low water at Butler. At this time the high water at Butler was about 55 feet higher than the water in the Ohio, and the average slope was less than 2 feet per mile. By the evening of February 11 most of the water was out of the Licking, except the backwater from the Ohio.

**Second backwater rise at Cincinnati.**—A second rise in the river between Point Pleasant and Portsmouth started on February 9, and by the morning of the 10th the stage at Portsmouth was 23 feet, or 27 feet lower than at Cincinnati, although Portsmouth is 113 miles upriver from Cincinnati. As the current in the Ohio at Cincinnati was very slow for such a high stage the first part of the rise from Portsmouth did not reach Cincinnati until the night of February 10-11. At this time the amount of water from the Licking began to decrease but this decrease was offset by the rise from above in the Ohio, so that the rise at Cincinnati continued almost steady at the rate of 0.2 feet per hour during the 10th and 11th. A careful estimate of the velocity of the current at 2 p. m. on February 11 at Cincinnati showed it to be less than 2 miles per hour, while the average velocity for a stage near 60 feet is between 6 and 7 miles per hour.

On the morning of February 12 the river stage was about 60 feet from Cincinnati to Aurora, Ind., and the backwater effect of the Sugar Creek gorge extended from North Landing to Dam No. 33 above Maysville, a distance of more than 100 miles. The stage at Portsmouth, above the pool, was 23.2 feet lower than at Cincinnati, and the stage at Dam No. 39, below the gorge, was 29.4 feet lower than at Aurora. The river was rising above at this time. On February 3, when the river was falling at all places above the gorge, the stage at Portsmouth was 32.1 feet lower than at Cincinnati, and at Dam No. 39 it was 26.2 feet lower than at Aurora.

**Break of Sugar Creek gorge.**—From the time the ice jammed in the river above Sugar Creek during the night of January 31-February 1 until February 12 there was very little change in the gorge. The temperature was mostly above freezing after February 6, and on February 11 the maximum was 57°, but this comparatively high temperature had very little apparent effect on the very hard ice in the gorge. Even on the surface the ice melted very little, but did loosen somewhat along the banks.

About 8:40 a. m. on February 12 the ice broke a mile below Dam No. 39, 4 miles upriver from Vevay, Ind., and moved down the river. A few minutes later the ice began to bulge up in front of the dam and water began spurting up through the cracks. The ice next began moving in the center of the river, very slowly at first, but gradually increased in velocity during the forenoon with a rapidly rising river. Practically all of the ice had passed out below the gorge leaving open water free of ice. The strong wind and high temperature during the forenoon helped considerably in breaking the gorge. At Louisville the wind averaged 46 miles an hour from the southwest, between 10 a. m. and 1 p. m., with a maximum velocity of 60 miles, and at Cincinnati it averaged 31 miles per hour, with a maximum velocity of 52 miles. Sugar Creek is on a line between Louisville and Cincinnati and directly northeast of Louisville. With the river free of ice below large waves pounded against the foot of the gorge. The high wind, with a temperature of about 60°, blew against the surface of the gorge and melted the ice rapidly on the surface and in the crevices along the surface, and probably moved or swayed slightly many of the large hills of ice extending from 20 to 30 feet above the surface, causing cracks and crevices through the gorged ice. At about 11:30 a. m., the same day the ice showed signs of breaking at the head of the gorge. It started and stopped several times during the next hour at 2 miles below North Landing and at Rising Sun. Between 12:30 and 1 p. m. it began to move from Sugar Creek to Rising Sun. The gorge ice passing Dam No. 39 during the early afternoon consisted principally of huge cakes of ice, some of which, striking the top of the cofferdam 25 feet under the surface of the water, would rise to a height of 25 to 30 feet above the surface when rolling over the cofferdam. This ice was clean and comparatively free of debris. Later the ice became more broken, and the first broken barges and boats which had been held in the gorge at North Landing began to pass Dam No. 39 at about 4 p. m. Between this time and dark 68 pieces of boats and barges of all descriptions were counted passing in the ice. Although the principal break in the gorge occurred at 1 p. m. it took more than seven hours for the gorge to completely break.

As soon as the gorge broke the river began falling rapidly, and, with the increasing current, all of the gorged ice above started moving. At Aurora the ice started moving at 2 p. m. and the river fell 5 feet in the next two hours. At Fernbank, 13 miles below Cincinnati, the ice started moving at 2:15 p. m. and the river fell 4 feet in the next 2 hours and 45 minutes. At Cincinnati the river reached a crest of 61.8

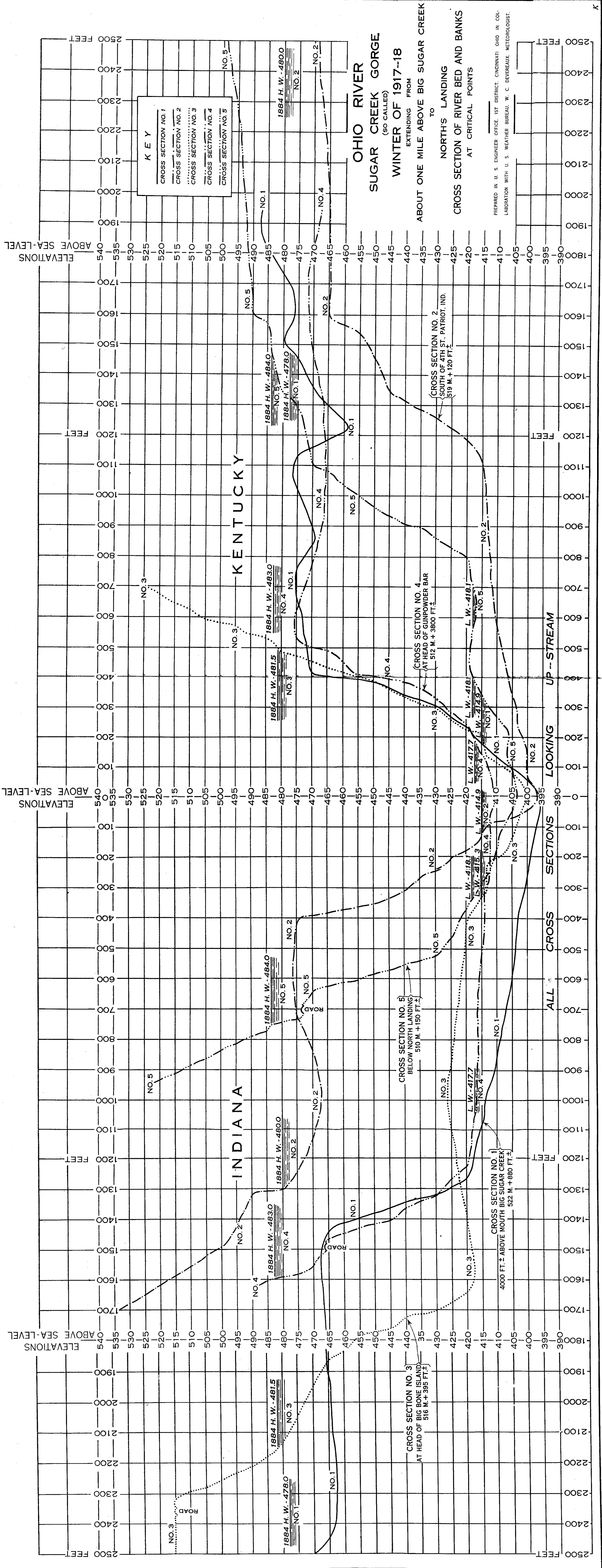


Fig. 2.—Cross sections Ohio River in Sugar Creek gorge. (Positions of cross sections are indicated on figure 1. Compare also figure 1a.)



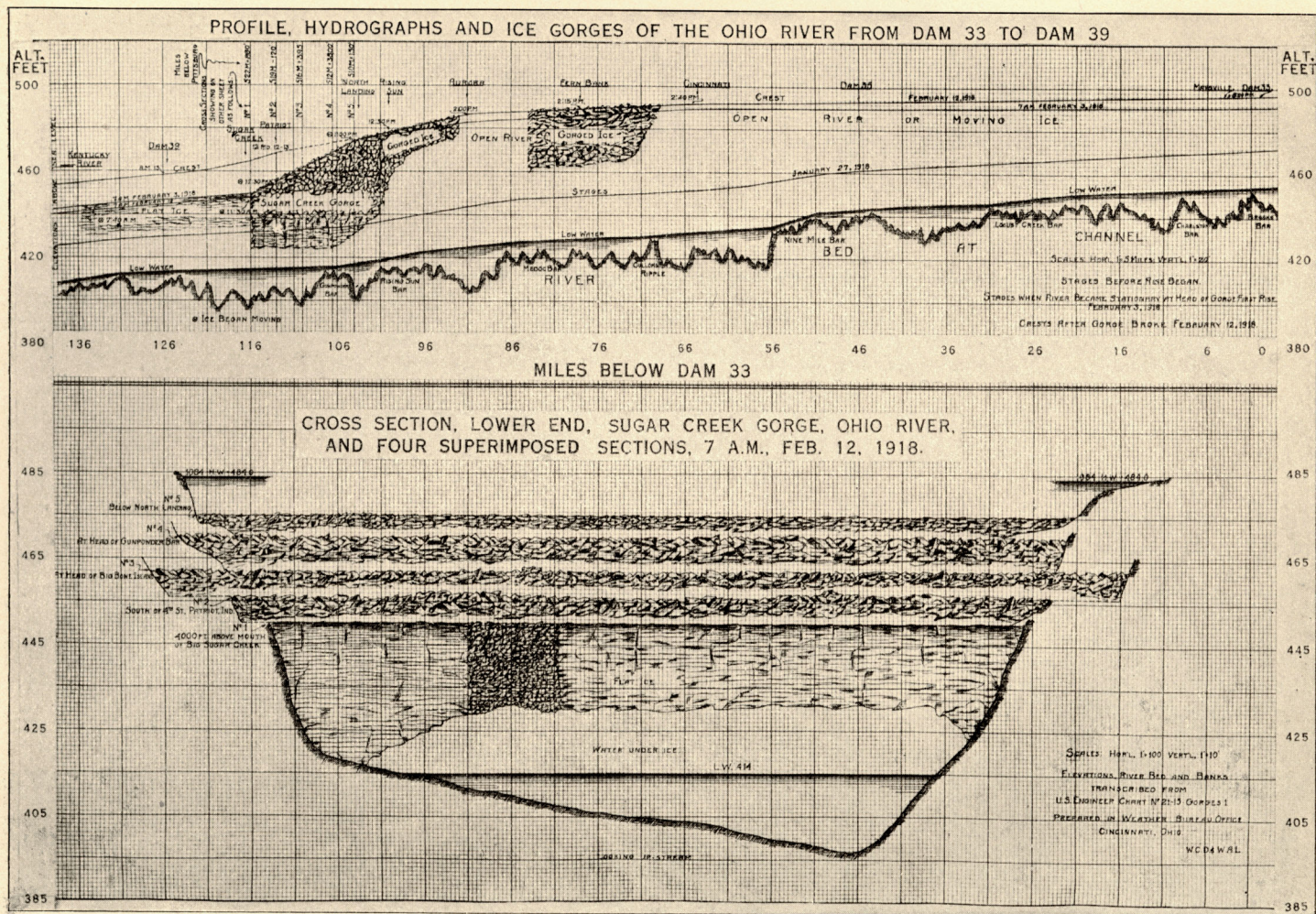


Fig. 3.—Profile and hydrographs, Ohio River and superposed cross sections of Sugar Creek gorge.

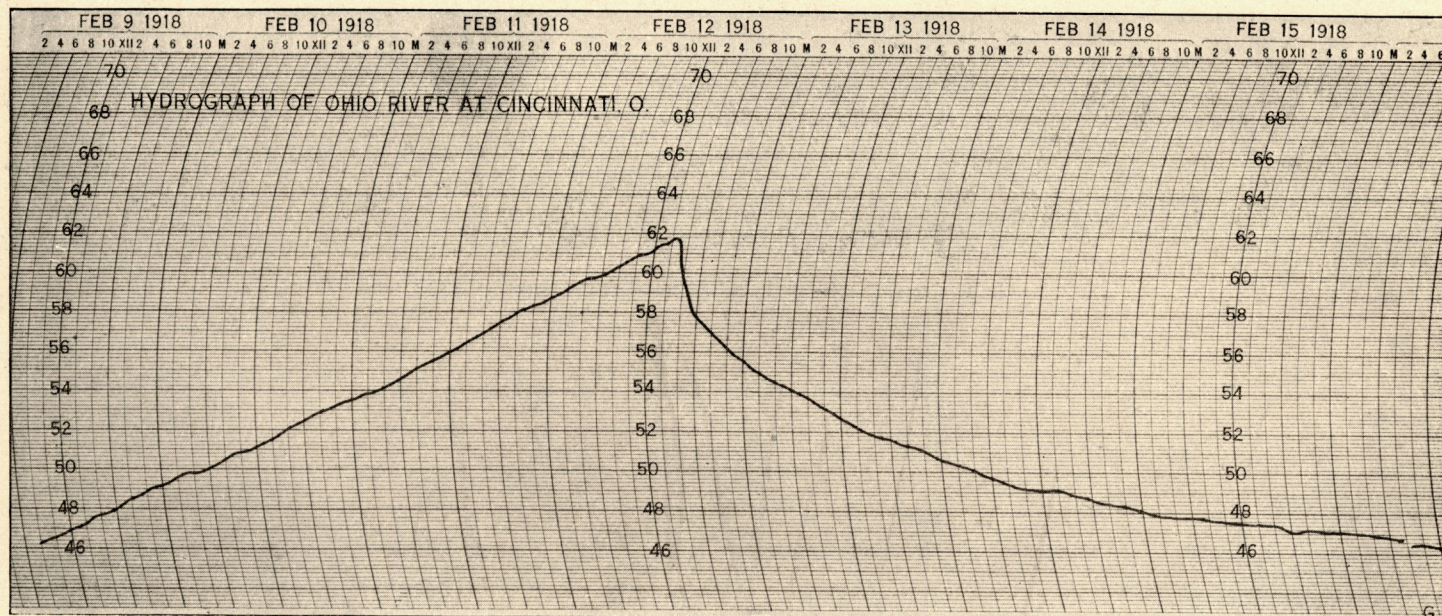


Fig. 4.—Hydrograph Ohio River at Cincinnati, Ohio, Feb. 9-15, 1918.





Fig. 5.—Gorged ice below Southern Railway bridge at Cincinnati, Ohio.



feet at 2:40 p. m. In the next 5 minutes it fell 0.2 feet, but in the 15 minutes between 2:45 p. m. and 3 p. m. it fell 1.1 feet. After 3 p. m. the rate of fall gradually decreased but continued rapid for the following two days. At Dam No. 33, 104 miles above the gorge, the river became stationary at 8 p. m. and continued so for 24 hours, although the river at Portsmouth above had been rising 0.2 foot per hour, or more, for several days. By the morning of the 14th the river was below flood stage at all places in the Cincinnati district.

Below the gorge the river rose rapidly (about 2 feet per hour) for the first 5 hours after the break and then rose more slowly. At Patriot, within the gorge and 3 miles from the lower end, the crest was between 55 and 56 feet about midnight of February 12-13, and at Dam No. 39, 10 miles below the gorge, the crest was 44.8 feet the following morning.

**Warnings.**—Warnings of the floods and the breaking of the ice gorges were issued whenever possible, and the river interests were kept fully advised of the conditions at all times. It was not possible to issue warnings for the floods at Pikeville, Williamson, and Logan, as in each case these places are the ones farthest up the tributaries from which river or rainfall reports were received.

At 9 a. m. January 23, 1918, warnings were issued that the ice gorges would break in the Ohio from the mouth of the Kanawha to below Ashland that afternoon and night, and from below Ashland to the mouth of the Kentucky within 36 to 48 hours. The ice gorges broke at all places as forecast, except at the Sugar Creek gorge.

During January 29 the warnings were repeated for the river from Portsmouth down, and special bulletins were issued every hour giving progress of the breaking of the gorges.

Warnings were not issued for flood stages in the Ohio above Cincinnati and none occurred. The morning forecast of January 30 contained a warning that flood stage might be exceeded at Cincinnati if the gorges below held. The river passed the flood stage at 8:30 a. m. January 31 and all interests were advised to keep a few feet above the rising water, as the river would continue to rise if the gorge below held. From January 30 to February 2, when the river was falling, bulletins were issued about every hour and three telephones were in almost constant use giving out the information.

At 6 p. m. February 9 warnings were issued that if the gorge in the Licking broke the river at Cincinnati would rise 5 to 10 feet. The warning was telephoned to all the river interests. The gorge did not break but the river rose quite rapidly and passed the flood stage again the next morning.

On February 10, 11, and 12, warnings and special bulletins were issued at frequent intervals. Briefly the forecasts were as follows:

**February 10, 9 a. m.**—"If ice gorge below Butler in Licking breaks river at Cincinnati will rise sharply several feet."

**February 11, 9 a. m.**—"The danger of a further big rise from the Licking is apparently passed. The river from Cincinnati to Rising Sun will continue rising about 0.2 foot per hour for the next two days or longer if the gorge above Sugar Creek holds, and the stage at Cincinnati will go above the 60-foot stage. If the gorge goes out, the river will begin to fall."

**February 11, 11 a. m.**—"For region below gorge.) Gorge above Sugar Creek may break or disintegrate within next day or two and there will be a decided rise in river below of about 20 feet."

**February 12, 9 a. m.**—"If gorge above Sugar Creek holds the river at Cincinnati will rise about 0.2 foot per hour this afternoon and to-night, reaching a stage between 64 and 65 feet Wednesday morning, after which time, if gorge still holds, the river will probably not change much."

A telephone message relayed through four exchanges was received at 2 p. m., February 12, stating that the gorge had broken. After this had been verified by the traffic chief of the telephone company and a similar report obtained from the wire chief of the Western Union Telegraph Co., at Louisville, Ky., the information was distributed by special bulletins and telephone.

**Losses from floods and ice gorges.**—Losses sustained by river craft as a result of the breaking of the ice gorges between January 29 and February 12, 1918, from the mouth of the Kanawha to the mouth of the Kentucky, are estimated at \$333,000. This includes the loss of the Baltimore & Ohio bridge (about \$200,000) across the Great Miami near the mouth. The Marine Underwriters estimate that the loss to river interests were between \$600,000 and \$650,000, exclusive of the Baltimore & Ohio bridge.

The losses due to floods in the Guyandotte and Big Sandy Valleys, and the two floods in the Ohio from Cincinnati to Rising Sun, Ind., are estimated as follows:

- (1) Loss of buildings, factories, bridges, etc..... \$350,000
- (2) Loss of farm property..... 5,000
- (3) Loss of farm property due to suspension of business..... 800,000

Value of property saved by warnings, \$3,000,000.

TABLE 1.—Hourly stages of the Ohio River at Cincinnati from 6 a. m. to 7 p. m. from Jan. 30, 1918, to Feb. 6, 1918, and from Feb. 9, 1918, to Feb. 14, 1918.

[Feet above gage zero whose altitude is 429.8 feet M. S. L.]

Date.	A. M.						Noon.	P. M.						
	6	7	8	9	10	11		1	2	3	4	5	6	7
1918.														
Jan. 30	22.7	23.2	25.0	26.8	27.8	35.2	33.3	41.0	43.0	45.0	46.2	45.2	44.8	44.7
31	48.5	49.4	49.6	51.1	52.2	54.8	55.7	56.3	56.9	57.1	57.5	58.0	58.3	58.6
Feb. 1	60.7	60.8	60.9	61.0	61.0	61.0	61.0	61.1	61.1	61.1	61.2	61.2	61.2	61.2
2	61.0	61.0	61.0	60.9	60.8	60.7	60.6	60.6	60.6	60.4	60.4	60.3	60.2	60.1
3	59.2	59.1	59.0	58.9	58.8	58.7	58.6	58.5	58.4	58.3	58.1	57.9	57.7	57.6
4	56.6	56.5	56.4	56.3	56.2	56.1	56.0	55.9	55.8	55.7	55.6	55.5	55.4	55.3
5	54.1	54.0	53.9	53.8	53.6	53.5	53.4	53.2	53.1	53.0	52.9	52.8	52.7	52.6
6	50.8	50.7	50.7	50.6	50.5	50.4	50.4	50.3	50.2	50.0	49.9	49.8	49.7	49.6
9	46.1	46.2	46.3	46.5	46.7	46.8	47.0	47.0	47.2	47.5	47.6	47.8	48.0	48.3
10	50.1	50.3	50.5	50.8	50.9	51.0	51.2	51.4	51.6	51.8	52.0	52.2	52.4	52.6
11	54.7	54.9	55.1	55.3	55.5	55.8	56.0	56.2	56.4	56.8	57.0	57.3	57.6	57.8
12	60.1	60.3	60.5	60.7	60.9	61.0	61.3	61.5	61.6	60.5	58.8	58.1	57.4	57.1
13	54.0	53.8	53.5	53.2	53.0	52.8	52.6	52.4	52.2	51.9	51.8	51.6	51.5	51.3
14	49.6	49.4	49.3	49.2	49.1	49.0	48.8	48.9	48.8	48.7	48.5	48.4	48.3	48.2

The crest stage in the first rise was 61.2 feet from 4 p. m. to midnight of February 1.

The crest stage in the second rise was 61.8 feet at 2:40 p. m. February 12.

River stages at Cincinnati at frequent intervals on February 12 after the breaking of the gorges below:

	Stg.		Feet.		Feet.
2:30 p.m.	61.7	3:28 p.m.	59.6	4:27 p.m.	58.6
2:40 p.m.	61.8	3:32 p.m.	59.5	4:30 p.m.	58.4
2:45 p.m.	61.6	3:35 p.m.	59.4	4:40 p.m.	58.3
3:00 p.m.	60.5	3:40 p.m.	59.3	4:45 p.m.	58.2
3:07 p.m.	60.4	3:43 p.m.	59.2	5:00 p.m.	58.1
3:15 p.m.	60.2	3:45 p.m.	59.1	5:07 p.m.	58.0
3:18 p.m.	60.0	3:48 p.m.	59.0	5:25 p.m.	57.8
3:20 p.m.	59.9	4:00 p.m.	58.8	5:32 p.m.	57.6
3:25 p.m.	59.7	4:15 p.m.	58.7		

—W. C. Devereaux, Meteorologist in Charge.

### Louisville, Ky., river district.

Owing to the remarkable cold weather which prevailed during practically the whole of December, 1917, and January, 1918, the average temperature of both months being considerably lower than for any of the corresponding months since the establishment of the national weather service in 1871, ice of unusual thickness formed on all the streams and rivers in the district. The Kentucky River was frozen, with ice more than 1 foot thick, from its source to its mouth. Also, the Ohio became covered with ice equally thick from the mouth of the Kentucky River to Cloverport, Ky., except over the falls of the Ohio at Louisville and for a mile or two above the Government dam at the same place; and even in this latter stretch there was heavy ice near the shore. The harbor and the canal at Louisville were kept open by breaking the ice with boats. The ice in these rivers and streams, except as mentioned, remained intact up to near the end of January, there being no thawing weather of sufficient length or any heavy rains to loosen and break it up.

**Kentucky River.**—About January 26 heavy rains set in over the head-water tributaries of the Kentucky River and continued during the greater portion of three days. This rain fell over sections already covered with deep snow, and as the temperature was above freezing, the combined rain and snow water resulted in great floods and much damage in the upper reaches of the Kentucky. In the upper Kentucky River stages approaching the highest on record were reached. The town of Beattyville was inundated for several hours, a flood crest of about 45 feet being reached January 29. The high waters broke up the ice, which was carried down stream forming gorges and causing large loss to log booms and river craft. The damage along the upper and middle Kentucky above Frankfort is estimated to have been about \$200,000. There was little or no damage at Frankfort, although a menacing gorge formed just below that city during the night of the 28-29th. However, the gorge broke and passed out during the afternoon of the 29th. A crest slightly above flood stage was reached at Frankfort. Below Frankfort the only damage of consequence was done at the mouth of the Kentucky River on January 30, when the ice masses from that river passed out into the Ohio. Here a number of boats, including sev-



eral of the large Ohio River boats, had sought harbor in anticipation of damage from the ice in the Ohio. These boats were carried out into the Ohio by the heavy ice, and most of them crushed, sunk, or damaged. The loss here is estimated to have been about \$100,000. Also one man was drowned. The ice floes from the Kentucky, containing boats and wreckage, lodged in the Ohio about 2 miles below the mouth of the Kentucky, but continued on down the Ohio with the breaking of the ice at Madison on February 1. The most valuable boat in this floe, and one of the largest excursion boats plying the Ohio, the "Island Queen," was finally brought to shore and saved at Louisville.

**Ohio River.**—The most important ice gorge and the one producing by far the most menacing situation in the Ohio and for the Louisville district, was the one that formed in the Big Sugar Creek bend, about 81 miles above Louisville. (See pp. 87-89.)

The Sugar Creek gorge was something over 15 miles in length, and produced a difference in water level above and below of 30 feet. This gorge held more or less firmly until February 12, being gradually added to until its length became nearly 30 miles. In the meantime practically all the ice in the entire Louisville district, which is below the gorge, broke up and passed out.

February 1, about noon, the whole field of ice in front of and immediately below Madison moved in one great sheet, carrying with it a number of barges and several river craft tied up there, the damage being about \$20,000. February 1, about 9:50 a. m., shore ice at the foot of Sixth Street, Louisville, broke and passed out over the dam, carrying away and destroying the houseboat of the Louisville Power Boat Club and nine motor boats, one worth about \$7,000, the loss here being about \$20,000. About 3 p. m. great ice sheets immediately above Louisville, near the Louisville Water Works pumping station, moved out in one great mass, carrying with it a number of coal barges and many small boats, causing a loss of about \$25,000.

February 2, heavy ice floes containing many river craft and wreckage of all kinds passed by Louisville the greater part of the day. The heavy ice swept away portions of the Government boulevards at Louisville, the extent and cost of damage to which can not be even approximated until a low stage of water permits a careful examination. By February 4 the ice had about all passed out of the Louisville district. Much of the floating equipment used in the construction of the dam below West Point was carried away by the ice, but as considerable of this is expected to be rescued lower down the river, no estimate can be given as to the damage here, which is about the only damage of any consequence in the Louisville district below Louisville.

February 12, the Big Sugar Creek bend ice gorge began breaking up about 1 p. m., when about 6 miles of the lower end broke loose and moved out. This was soon followed by the breaking up and moving out of the whole gorge. The first heavy ice from the gorge reached Madison about 2:15 p. m. and Louisville about midnight. The river was filled from bank to bank with heavy floating ice, containing all kinds of river craft and wreckage, during all of the 13th. Very little, if any, of this wreckage, however, came from the section of river and tributaries under the Louisville district. On account of the open water that prevailed in this district during the 10 days preceding the breaking up of the gorge, all craft, wharf boats, etc., remaining that could be moved were taken to safe harbor. (raft to the value of more than \$1,000,000 was harbored in the Portland Canal, at Louisville, and all saved.)

The river, of course, rose rapidly after the breaking of the big gorge, but it did not reach the flood stage at either Madison or Louisville. A crest of 44.7 feet was reached at Madison about 3 p. m., February 13, and 26.7 (upper gage), 51.9 feet, lower gage, at Louisville at 6 a. m., February 14.

The ice floes reached Cloverport, 104 miles below Louisville, during the night of the 13th-14th. A flood crest of 42 feet (2 feet above flood stage) was reached at Cloverport in the early morning of February 15.

All river interests were kept fully advised and warned during the entire time of the critical situation produced by the ice, gorges, and damming of water.—F. J. Walz, *Professor of Meteorology in Charge.*

### *Evansville, Ind., river district.*

Floating ice made its appearance in practically all of the district during the first decade of December, 1917. River navigation ceased in all of the district, and the river froze over at most places between December 10 and 15; while the ice in the lower part of the district, from Mount Vernon, Ind., down, remained solid from this time until the general break-up occurred in February, 1918, it broke and moved slightly at most points above Mount Vernon on December 18; another movement also set in at all points in the upper and middle parts of the district during the night of December 22 and 23; the river was nearly clear of ice down to and including Henderson, Ky., from December 23 to 28, inclusive, but floating ice again appeared in all of that part of the district on December 29, and by January 3 or 4 the river, above Mount Vernon, was again filled with broken ice having but little, if any, movement; this condition continued until the night of January 11 and 12, when

the river was frozen entirely across at all points in the district for the first time since February, 1905. Many people crossed the river on the ice at all points in the district from January 15 to 21, inclusive; during this interval some hauling with teams was also reported to have been done across the river on the ice at, or near, Mount Vernon, Ind. The ice held firmly in all of the district until February 1, when the first signs indicating a general break-up made their appearance between the mouth of the Green River and Evansville, Ind.; the appearance of these signs in that part of the district was probably due to the running out of the Green River ice, which broke in the upper pools of that stream on January 25 and reached its mouth on February 1.

The general break-up and running out of the Ohio River ice in this district, began above Newburg, Ind., on February 2 from Newburg, Ind., down to include Henderson, Ky., on February 3, and from a point slightly above West Franklin, Ind., down, on February 4. Heavy ice running quite freely above Henderson until about 5 a. m. of February 4, when it began to gorge in the Evansville bend; river rose rapidly at points immediately above the jamming ice; at Evansville the river rose from a stage of a little less than 30 feet to a stage of 35.5 feet during the two hours ending at 7 a. m. of February 4. While the gorge continued to form in the Evansville bend, the ice containing considerable wreckage kept passing the Evansville wharf until 4 p. m. of February 4 when all movement ceased. By 7 p. m. of that date the gorge extended from about Howell, Ind. (just below the Evansville bend), up to above the mouth of the Green River, and by daylight of February 5 up to above Newburg, Ind., making the total length of the gorge (locally known as the Evansville gorge) about 15 miles. The ice in this gorge was the heaviest ever observed along this stretch of the river; it was solid and quite clear, and in front of Evansville the cakes in the gorge varied between 14 and 22 inches in thickness. (See fig. 7.)

The ice in the lower part of the district, from West Franklin down, which broke and began moving shortly before noon of February 4, continued running until about 9 p. m. of that date when it formed the second gorge in the district; this second gorge extended from about 4 miles above West Franklin, Ind., down far beyond the lower end of the Evansville River district, was in fact the upper end of an immense ice jam of nearly 100 miles in length, which was reported to have extended down the Ohio River to Birdsville, Ky.

The upper end of the district down to below Rockport, Ind., and a short stretch of river from Howell, Ind., down to Henderson, Ky., were practically free of ice from February 4 to 14.

The ice in the lower gorge began moving at West Franklin and Mount Vernon shortly after the noon hour on February 6, and at Uniontown, Ky., about noon of February 7; the river was free of ice from Henderson, Ky., and below after 3 p. m. of February 7, the only ice remaining in the district being the Evansville gorge.

The Evansville gorge held firmly until the night of February 10 and 11 when some movement occurred on the Kentucky side at its upper end near Newburg, Ind.; slight movements also occurred during the afternoon of February 11 in front of Evansville; during the early morning of February 12 slight movements occurred in various parts of the gorge, and by 4 p. m. of that date a general, continuous, but slow, movement had begun; by 6 p. m. the entire gorge appeared to be moving freely, and considerable floating property, abandoned in the ice, passed Evansville before dark; by daybreak of February 13, the main channel at Evansville was practically clear, with a fringe about 100 yards, wide of heavy ice remaining stranded on the Indiana bank; by morning of February 14 the ice from the Evansville gorge had moved down beyond the mouth of the Wabash, and while the Ohio River was not entirely free of floating ice, it had an open channel throughout the entire district. This condition was, however, of brief duration, as the heavy ice from the upriver gorges made its appearance in the upper end of the district on February 14; the upriver ice which was very heavy, and carried with it an immense amount of wreckage, passed through the district on February 14 and 15, filling the river from bank to bank. In passing through the district the upriver ice carried with it nearly all the ice that had been left stranded along this stretch of the river when the Evansville gorge went out. Except for some light floating ice in places, the Ohio was free of ice in all of the district by February 16.

The ice, in moving out, and through the district, did an immense amount of damage to all kinds of floating property, banks, inclines, etc. While there were, no doubt, a great many minor losses in various parts of the district that were unheard from, the principal losses will aggregate \$127,905, which were distributed as follows:

At Tell City, Ind. ....	\$300
At Owensboro, Ky. ....	14, 650
At Evansville, Ind. ....	31, 650
At Dam No. 48 (5 miles below Henderson, Ky.)..	59, 055
At Mount Vernon, Ind. ....	21, 000
At Uniontown, Ky. ....	1, 250
<b>Total.....</b>	<b>127, 905</b>





Fig. 6.—Ice left on banks at Fernbank, Ohio, as gorge broke .





Fig. 7.—Gorged ice in front of Evansville Ind., Feb. 5, 1918.



Fig. 8.—Gorge in Mississippi 4 miles south of Osceola Ark. (Ice resting on bar at this point.)



While some of the lost or damaged property will, very likely, be salvaged and repaired, the permanent losses in the district will, it is believed, be fairly represented by the foregoing total as the minor losses which were not reported will fully equal in value the property salvaged.—*Albert Brand, Meteorologist in Charge.*

### *Cairo, Ill., river district.*

As applying to the months of December, 1917, and January, 1918, the winter of 1917-18 broke all records for heavy snow and low temperature. That is certainly true at Cairo and is probably true as applied to the lower Ohio and Tennessee Rivers.

At Cairo, Ill., December 9, 1917, a minimum temperature of  $-7^{\circ}$  F. was recorded, the earliest date in that month when such severe temperature has occurred within the history of the station extending back 46 years; January 12, 1918, a minimum temperature of  $-16^{\circ}$  occurred, equal to the lowest ever recorded here in any month; the mean temperature for December, 1917,  $28.7^{\circ}$ , was the lowest mean for that month ever recorded with the exception of  $26.4^{\circ}$ , in December, 1876; and the mean temperature for January, 1918,  $21.0^{\circ}$ , was about 4 degrees lower than that of any previous month, of record. Taking the two months, January, 1918, and the month preceding, combining their mean temperatures and dividing by 2, giving  $24.8^{\circ}$  as a basis of comparison, we had a mean daily average 4.6 degrees lower than that of any previous two consecutive months in the history of the station.

During the 62 days comprising December, 1917, and January, 1918, 35 days, had a maximum temperature below  $32^{\circ}$ .

As a consequence of the extremely cold weather ice formed in the lower Ohio and Tennessee Rivers in quantities never before recorded, and which the oldest inhabitants held neither in memory or tradition. January 12, 1918, people crossed the Ohio River at Cairo on the ice for the first time known, shore ice being about 18 inches in thickness, that in the channel probably about 2 inches.

The Mississippi in the vicinity of Cairo has previously been frozen solidly enough to drive cattle across, and no unusual records, relative to ice in that stream, were made, except that portion below Cairo where ice from the Ohio affected it.

The Ohio, below the mouth of the Wabash, closed about December 11, 1917, remained so for about 10 days, open until January 1, 1918, closed until February 3, when slight movements occurred, the final break-up occurring during the night of February 6-7; the maximum thickness of ice in the vicinity of Shawneetown, Ill., was 18 inches, and when the ice went out considerable gorging occurred, the river going above flood stage on the 8th, ice covering the fields on both sides of the river in that vicinity to a distance of one-half mile, breaking down fencing and barns; the fencing and buildings on this class of land are usually of flimsy structure and no considerable amount of damage resulted; however, a steamboat and three or four gasoline boats were destroyed, having a total valuation of \$15,000.

In the Tennessee River, at Florence, Ala., gorges described as 70 feet high formed at the canal and a number of families removed from their houses as a precautionary measure, although no damage eventually occurred; the main channel of the stream did not close at any time, but seemed to almost close at intervals from January 12-16, 1918. Maximum thickness of shore ice was about 18 inches.

At Riverton, Ala., also, the main channel remained open, some small craft being damaged by floating ice, having a valuation of \$1,000.

At Savannah, Tenn., a gorge formed about 8 feet in height and another gorge, upstream, was reported to have been 14 feet in height; the damage in that vicinity amounted to about \$2,200 in all, lumber and buoys used in the operation of the local ferry boat being carried away by ice and flood.

Ice appeared at Johnsonville, Tenn., December 16, channel remained open until January 13 and 14, at which time it appeared possible to cross on foot, although the passage was not attempted by anyone; channel cleared January 15, with some slight damage to small boats, none being lost; the river became free from ice January 28-29.

The mouth of the Tennessee River, near Paducah, Ky., being reputed free from ice hazards, has been used as a winter anchorage for many steamboats, especially upper Mississippi River craft, for a number of years. The unprecedented ice conditions prevalent in the Tennessee and lower Ohio Rivers during the past winter made the situation there hazardous, and during the early morning of January 29, 1918, gorges carried away or sunk 8 steamboats, valued collectively at \$350,000. The steamers *John L. Lowry* and *Joe Fowler* were not carried away with the ice, but were damaged to the extent of about \$2,500; also, the ferryboat *City of Cairo*, in winter harbor at the mouth of the Tennessee, was damaged about \$1,000.

At Metropolis, Ill., Joppa, Ill., and Mound City, Ill., considerable damage was done with the passing of the gorge January 29, but the full extent of damage has not been estimated.

At Cairo, two wharf boats were sunk, one wharf boat damaged by being pushed ashore by the ice, and all boats in the harbor were

injured. The *Sprague*, the largest towboat plying in inland waters, was carried away but has since been recovered; the two wharf boats sunk had been in use a great many years, and were not of high intrinsic value, except as a matter of utility; the entire local damage to river craft probably amounted to \$50,000.

At Hickman, Ky., on the Mississippi below Cairo, a steamboat belonging to the Mengel Box Co., was reported lost, value not estimated; and slight damages resulted from the passage of the gorge carrying away small craft and two houseboats at New Madrid, Mo.

A gorge at Columbus, Ky., held from late in December (Dec. 29, 1917) until January 30, 1918, breaking when the Ohio-Tennessee River gorges were forced upon it; foot passage between Kentucky and Missouri, across the frozen Mississippi, occurred at that point between January 10 and 15.

Taken altogether, ice conditions during the past winter throughout this river district were without precedent.—*R. T. Lindley, Meteorologist in Charge.*

### THE MISSISSIPPI RIVER.

#### *St. Paul, Minn., river district.*

The channel closed at Robert Street bridge (location of gage) during the night of December 3-4, 1917; the thickness of the ice on Monday, December 10, was 7 inches; it increased to a maximum thickness of 20 inches on February 11. During the afternoon and night of Sunday, March 3-4 the ice ran out, and on the morning of March 4 the channel was open from the High Dam (about 3 miles above the mouth of the Minnesota River) to South St. Paul (about 5 miles below the gage). During the entire winter there was a narrow strip of open water along the shore on the gage side, from a large trunk sewer, about a half mile above the gage, to a mile below the gage.

The breaking up of the ice was gradual and without any rise of the water and therefore without any damage resulting.

At this date—March 20—the river is open from St. Anthony Falls, at Minneapolis, to near Hastings, and possibly farther down (20 miles).

It is expected that the ice in Lake Pepin will open in a few days.—*J. N. Ryker, Meteorologist in Charge.*

#### *Dubuque, Iowa, river district.*

The Mississippi River is now (Mar. 16, 1918) open at and near Dubuque. No gorges have formed, and the break-up has been wholly without damage. In spite of the severity of the past winter the thickest ice in this section was about 2 feet, which is not unusual. The heavy snow covering prevented extra heavy ice such as occasionally forms during a cold but "open" winter.

On the average the Mississippi River opens up here on March 15, and this year the opening was two days earlier than the average. Some of the rivers of this district, and also a portion of the Mississippi above Dubuque, are still frozen, but I think the break-up will be soon and without unusual incident throughout the river district.—*J. H. Spencer, Meteorologist in Charge.*

#### *Davenport, Iowa, river district.*

No gorges worthy of mention formed in the Davenport district during the winter of 1917-18. Notwithstanding its great thickness at the beginning of February, the ice broke up about two weeks earlier than usual and passed out quietly, without doing any particular damage. The river opened at Muscatine on March 1, at Davenport and Clinton on March 2, and at Le Claire on March 3.—*J. M. Sherier, Meteorologist in Charge.*

#### *Keokuk, Iowa, river district.*

The Mississippi River was open for 2 miles south of the Keokuk Dam during the entire winter owing to the discharge from the power house.

At Warsaw, Ill., 5 miles south, it was frozen, and teams were crossing on the ice until the middle of January.

By February 14 the ice had moved out from the lower Des Moines and from the Mississippi at Warsaw, gorging between Gregory and Canton, Mo. This gorge caused a rise of 3 feet at Warsaw, and the rise extended to Keokuk.

At Ottumwa, Iowa, on the Des Moines River, the ice broke up on February 12, a gorge formed north of Ottumwa causing a fall of 3 feet by the 19th, the river closing temporarily by the 19th and opening permanently on the 22d.

North of Keokuk the ice formed during the winter to the thickness of 24 inches, breaking up for a short distance above the dam by February 18, and by February 25 the ice was broken up far above the dam.—*Fred J. Gosewisch, Observer in Charge.*